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ORIGINAL ARTICLE

Immediate and Long-Term Effects of Hippotherapy on Symmetry of Adductor Muscle Activity and Functional Ability in Children With Spastic Cerebral Palsy

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ABSTRACT. McGibbon NH, Benda W, Duncan BR, Silkwood-Sherer D. Immediate and long-term effects of hippotherapy on symmetry of adductor muscle activity and functional ability in children with spastic cerebral palsy. Arch Phys Med Rehabil 2009;90:966-74.

Objectives: To investigate the immediate effects of 10 minutes of hippotherapy, compared with 10 minutes of barrel-sitting, on symmetry of adductor muscle activity during walking in children with cerebral palsy (CP) (phase I). To investigate the long-term effects of 12 weeks of hippotherapy on adductor activity, gross motor function, and self-concept (phase II).

Design: Pretest/posttest randomized controlled trial plus clinical follow-up.

Setting: Outpatient therapy center.

Participants: Children with spastic CP (phase I: n=47; phase II: n=6).

Interventions: Phase I: 10 minutes of hippotherapy or 10 minutes of barrel-sitting; phase II: 12 weekly hippotherapy sessions.

Main Outcome Measures: Phases I and II: adductor muscle activity measured by surface electromyography. Phase II: gross motor function and self-perception profiles.

Results: Phase I: hippotherapy significantly improved adductor muscle asymmetry ($P<.001$; $d=1.32$). Effects of barrel-sitting were not significant ($P>.05$; $d=.10$). Phase II: after 12 weeks of hippotherapy, testing in several functional domains showed improvements over baseline that were sustained for 12 weeks posttreatment.

Conclusions: Hippotherapy can improve adductor muscle symmetry during walking and can also improve other functional motor skills.

Key Words: Cerebral palsy; Electromyography; Horses; Movement; Muscle spasticity; Rehabilitation.

CEREBRAL PALSY IS A disorder of movement and postural control that results from an insult to the developing fetal or infant brain. More than 70% of children in the United States with CP have spasticity,[1] characterized by excessive muscle tone, velocity-dependent overactivity, restricted movement, and abnormal distribution of postural tone.[2,3] Spasticity is typically distributed unevenly throughout the child's trunk and limbs and is thus a major cause of abnormal postures as well as left-right asymmetry between homologous muscle groups. In children with CP, imbalanced muscle activity may also result from muscle hypoextensibility, soft tissue contractures, spasticity in synergistic muscle groups, and compensatory postures. Of particular concern are the effects of spasticity and related impairments on the adductor muscles of the thigh.

In children with spastic CP, asymmetric and hyperactive adductor muscle activity may cause reduced hip range of motion, uneven bone growth, degenerative bone changes, hip subluxation, and possible dislocation.[4,5] In addition, in ambulatory children adductor muscle imbalance can cause uneven weight-bearing, hip, knee, and ankle malalignment, painful joints, and postural asymmetries throughout the trunk, thus affecting midline orientation; balance; and normative, efficient walking.

Physical therapy for children with adductor spasticity is designed to promote a child's highest functional ability while minimizing the effects of adductor hyperactivity and asymmetrical weight-bearing in order to avoid secondary orthopedic complications related to these impairments. More aggressive interventions such as tendon release surgery, selective dorsal rhizotomy, baclofen, osteotomy, and injection of botulinum toxin offer improvement to some yet have the potential for adverse reactions.[6-8]

Hippotherapy is a physical therapy treatment strategy using equine movement. It has been used for over 25 years in the treatment of children with spastic CP[9] as well as other conditions such as multiple sclerosis, traumatic brain injury, developmental delay, muscular dystrophy, and sensory impairments.[10] Previous studies have reported the benefits of equine movement for children with CP, including improved gross

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List of Abbreviations

APA	anticipatory postural adjustments
CP	cerebral palsy
EMG	electromyography
GMFCS	Gross Motor Function Classification System
GMFM-88	Gross Motor Function Measure-88
ICF	International Classification of Functioning, Disability, and Health
mV	microvolts
sEMG	surface electromyography
SPPC	Self-Perception Profile for Children

motor function,[11,12] walking energy expenditure,[11] and trunk postural coordination.[13] To our knowledge, no studies have focused specifically on adductor muscle activity using surface electromyography.

sEMG is a tool that is often used to study muscle activity as it relates to posture and movement because postural changes are known to affect sEMG recordings.[14] Using sEMG, Al-Khabbaz et al[15] analyzed trunk and lower-extremity muscle activity and postural changes that result from carrying different backpacks. Aruin[16] studied the effect of body asymmetry on APA during a standard load-release task. He found that the asymmetrical APA EMG patterns were associated with asymmetrical body positioning and concluded that body asymmetries play an important role in the control of upright posture.

An exploratory pilot study using surface EMG and previously carried out by this research group supported the assumption that children with CP may have more adductor asymmetry during typical walking than children with no disabilities. We first measured electrical activity of the adductor muscles in 9 children with spastic CP (age 4–9y) as they ambulated at self-selected speed along a marked walkway. The difference in mean mV between left and right adductor activity for each child was calculated and recorded as the child's asymmetry score. The higher the asymmetry score, the greater the difference between left and right adductor muscle activity for that child. The mean ± SD of the asymmetry scores for the CP group was 38.61±41.76mV (range=10.9–133.5mV; unpublished data). This wide range was not unexpected because of the marked individual clinical variability of children with spastic CP.[17] For comparison, a group of 8 children with no known motor impairments (age=6–10y) were also tested during ambulation at self-selected speed. In contrast to the group with CP, the mean of the asymmetry scores ± SD for the group with no disabilities was 2.30±2.23mV (range=0.4–6.2mV), demonstrating that children with CP may have more adductor asymmetry than typically developing children.

In a larger pilot study, Benda et al[18] used remote sEMG to investigate the effects of hippotherapy on a variety of asymmetric muscle groups in 13 children with CP. Each child was randomized to either one 8-minute session on the horse or one 8-minute session sitting astride a stationary barrel. Muscle groups tested included posterior cervical paraspinals, thoracic paraspinals, and lumbar paraspinals, as well as the adductor and abductor muscle groups of the upper thigh. Using the data from the single most asymmetric muscle group for each child, the study demonstrated significant improvement in muscle symmetry for the hippotherapy group and no significant change in the group sitting astride the barrel. Although no single muscle group showed significant improvement across all children, the greatest improvement was found in the adductor muscles. These preliminary findings, plus the need for noninvasive treatment options for children with adductor spasticity and related muscle imbalance, provided the rationale for our current investigation.

METHODS: PHASE I

Immediate Effects of Hippotherapy

The purpose of phase I was to investigate the immediate effects of one 10-minute session of hippotherapy, compared with one 10-minute session of barrel-sitting, on symmetry of adductor muscle activity during walking in children with CP.

There were 3 specific aims: (1) to expand the pilot study by Benda et al[18] using a similar design but with a larger number of subjects, (2) to focus specifically on changes in adductor muscles, and (3) to enhance the scientific rigor of the Benda[18] study by using digitized sEMG synchronized with videotape of all walking trials.

This study was a pretest/posttest randomized controlled trial. Effect sizes were estimated using our previous pilot study data.[18] The effect size for the adductor muscles for walking was 1.67. Assuming a large effect size (.80), an alpha level of .05, and power of .80, a sample size of 52 was recommended.

Participants

Fifty-eight children were recruited through physician or physical therapist referrals. Forty-seven completed all testing, with 25 randomized to the horse group and 22 to the barrel group (fig 1). Inclusion criteria consisted of (1) diagnosis of spastic CP made by a pediatric neurologist, (2) age 4 to 16 years, (3) ability to walk independently with or without an assistive device, (4) ability to comply with the study protocol and follow verbal directions, and (5) sufficient hip abduction to sit astride a horse or barrel with no evidence or report of hip dislocation. Exclusion criteria were (1) previous history of selective dorsal rhizotomy; (2) tonic clonic seizures (grand mal) uncontrolled by medication; (3) known allergy to horses, dust, or electrode adhesive; (4) surgical procedures, BTX-A injections, or lower-extremity casting within 6 months prior to testing; and (5) hippotherapy or horseback riding experience within 6 months prior to testing (table 1, phase I subject demographics).

Randomization was performed by an independent research assistant and allocated by order of enrollment. Assignments were revealed to participants only after completion of pretests. The study was conducted at an outpatient hippotherapy center accredited by North American Riding for the Handicapped Association. It was under the direction of a physical therapist (N.H.M.) certified as a Hippotherapy Clinical Specialist by the American Hippotherapy Certification Board. Pretesting and posttesting, including electrode application, were administered by an experienced pediatric physical therapist masked to the randomization. Prior to signing informed consents, full explanation of all procedures was provided to each child and to parents or caregivers. The study was approved by the Institutional Review Board of the University of Arizona.

Prior to baseline testing, each child was rated using the GMFCS[19]: level I, walks without restrictions; level II, walks without assistive devices but with some limitations; level III, walks with assistive devices; or level IV, walks short distances with assistive devices or uses powered mobility (see table 1). The rating system was employed to evaluate the potential relationship between degree of treatment response and level of disability.

Interventions

Hippotherapy (treatment arm: one 10-minute session of hippotherapy). Either a small or a medium-size horse with exemplary temperament; soundness; and free, rhythmic, symmetrical walking movement was used to accommodate variations in the size of the children. The horse was fitted with a pad and surcingle, and the child was placed sitting in a forward astride position. A horse handler led the horse on a designated circular track at a steady walk for 10 minutes, 5 minutes in each direction. A typical 30-minute hippotherapy session consists of an initial period of 5 to 10 minutes of passive muscle relaxation and postural adjustments solely in response to the horse's movement, followed by position changes and active exercises directed by the therapist.[11] This study, however, was deliberately designed to measure adductor activity after only the first 10 minutes on the horse in order to avoid additional extraneous

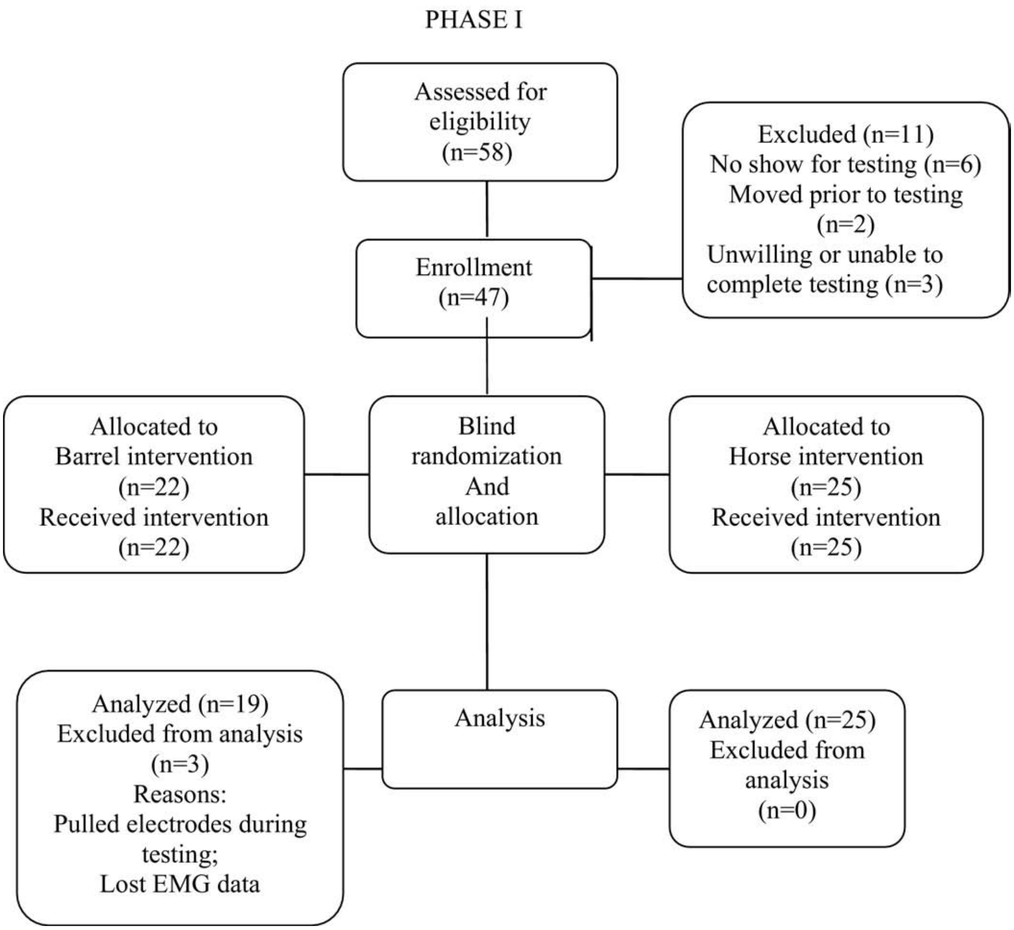

Fig 1. CONSORT flowchart.

variables resulting from position changes and therapist interaction with the child. A physical therapist and an assistant walked on either side of the child for security but did not provide postural support to the child. Each child was fitted with a safety helmet, regardless of randomization.

Stationary barrel (control arm: one 10-minute session of barrel-sitting). A stationary barrel comparable to a bolster found in a typical physical therapy clinic was created from a 55-gal drum (208.2L) approximating the girth of a horse, covered with a fleece pad, and mounted on supports at the approximate height of an average horse. A television with video cassette recorder playing a horse video was mounted in front of the barrel to encourage the child to maintain forward attention and quiet sitting. The child sat astride the barrel as if it were a horse, with the identical team of 3 assistants in place for the requisite 10 minutes. The children randomized to the barrel protocol received a reward ride on the horse after the completion of all testing and data collection.

Table 1: Phase I Subject Demographics

Demographics	Horse Group	Barrel Group	Summary
Sex (n)			
Male	16	11	27
Female	9	11	20
Age			
Mean	8y5mo	8y8mo	NA
Range	4y1mo–16y8mo	4y0mo–13y6mo	NA
Diagnosis (n)			
Spastic diplegia	12	13	25
Spastic quadriplegia	7	2	9
Spastic hemiplegia	4	3	7
Mixed	2	4	6
GMFCS (n)			
I	14	13	27
II	4	5	9
III	2	3	5
IV	5	1	6

Abbreviation: NA, not applicable.

Outcome Measure and Testing Protocol

Surface electromyography. Electrodes were applied symmetrically and bilaterally to the adductor muscle groups of the upper thigh according to standard placement guidelines.[20] The leads were connected to a small transmitter, which was carried by an assistant so as not to encumber the child during testing. Each child was instructed via standardized verbal instructions to walk at self-selected speed (the way you would normally walk) for 2 trials, 1 down and 1 back, along a 20-foot marked walkway. Throughout each trial, EMG data from adductor muscle activity as well as time-linked videography of the child's walking were recorded and saved to a computer. A walk

Table 2: Within-Group Comparison of Mean Asymmetry Scores

Group	Test	n	Mean Asymmetry Scores (mV)	95% Confidence Interval	Wilcoxon (*T*) Transformed to *z* Score	Exact Significance (2-tailed)	Effect Size Cohen *d*
HPOT	Pretreatment	25	111.21	39.97–182.45			
	Posttreatment	25	65.39	5.21–125.07			
	Change		↓45.82		.322 (T=10.67)	.000*	1.32‡
Barrel	Pretreatment	19	129.07	65.19–192.95			
	Posttreatment	19	130.29	33.29–228.70			
	Change		↑1.92		−3.511 (T=8.70)	.768†	.10

*Statistically significant decrease in adductor asymmetry in the hippotherapy group ($P<.001$).
†No significant decrease in adductor asymmetry in the hippotherapy group ($P>.05$).
‡Very large effect size.

trial was repeated if children played, waved an arm, turned their heads, or walked in an atypical manner (per parent or caregiver). Walking was unassisted by the therapist, but children were allowed to use their usual assistive devices if necessary and were asked to walk toward the parent or caregiver in order to facilitate a straight path of travel and forward visual attention. For each trial, the first 3 continuous full strides after start-up and prior to slow-down were marked and analyzed from, for example, left heel strike to left heel strike. Absolute differences in mV rather than percent of maximal voluntary contraction were recorded and used for analysis because the electrodes were not removed and replaced between assessments and because the focus of the study was the asymmetry of the actual muscle activity. For each child, the preintervention walking trials were used as the reference activity for comparison to the postintervention trials, an alternative normalization procedure that can be used for comparing muscle activity within the same subject during dynamic activities.[21]

After the pretests, sealed envelopes were opened to reveal randomization. Twenty-five children were randomized to the hippotherapy intervention, and 22 children were randomized to the barrel intervention. The electrodes were left in place during both interventions. After the intervention, the child performed the posttest walking trials on the marked walkway with the same standardized instructions. Test-retest reliability of .93 to .99 has been reported for 1 setting when electrodes are not replaced between trials.[22]

Remote sEMG data were collected via dual disposable Ag/AgCl wet-gel snap electrodes.[a] The electrodes were figure 8-shaped with an adhesive area of 4cm×2.2cm (1.575in×.866in). The diameter of each of the 2 circular conductive areas was 1cm (.394in), and the interelectrode distance was 2cm (7.87in). The electrodes were placed parallel to the fiber orientation of each muscle group tested. The signal was recorded with a multichannel telemetric EMG system (Telemyo[a]) with an amplifier bandwidth of 10 to 500Hz, input impedance more than 10 MedOhms, and minimum common mode refection of 85dB. Raw data were sampled at 1000Hz with a 12-bit A/D converter card[b] along with video data (MyoVideo[a]) and stored in a laptop personal computer for later analysis. Video data were collected with a camcorder and digitized using Dazzle Digital Video Creator.[c] Prior to analysis, the raw data were full-wave–rectified and smoothed with RMS 20ms (MyoResearch 2.02[a]). This same software was then used to calculate the mean EMG value for each trial.

Data Aggregation and Analysis

The two 3-stride segments were averaged to obtain 1 score (in mean mV) of muscle activity for the left adductors and 1 score for the right adductors. In the case of children who were unable or unwilling to ambulate 2 lengths of the walkway, 1 trial was accepted if a minimum of 3 strides was obtained, because 3 strides of EMG data per participant have been determined to be as reliable as 12 strides.[23] The absolute difference in mean mV between left and right adductor activity level for each child was calculated for the pretests and posttests and recorded as the child's pretest or posttest asymmetry score. The higher the asymmetry score, the greater the difference between left and right adductor muscle activity for that child. A group mean or average was determined by adding all of the childrens' asymmetry scores in each group (hippotherapy or barrel) for both preassessments and postassessments.

Data were analyzed using SPSS 15.0[d] with exact analysis package. After visual inspection of the data and analysis using the Kolmogorov-Smirnov test, it was determined that the groups did not have a normal distribution of data. Therefore, 2-tailed nonparametric tests of the Wilcoxon signed-rank test (T) (the smallest of the 2 sum of ranks) and the Mann-Whitney U test were used to assess within-group and between-group changes, respectively.[24]

RESULTS: PHASE I

Within-Group Analysis

After hippotherapy, the mean decrease (improvement) in the adductor muscle asymmetry score was 45.82mV, demonstrat-

Table 3: Between-Group Comparison of Mean Asymmetry Scores

Test	Group	n	Median	Range	Mann-Whitney *U*	Exact Significance (2-tailed)	Effect Size Cohen *d*
Pretreatment	Hippotherapy	25	50.00	7.37–830.79			
	Barrel	19	89.77	1.45–472.52	206.00	.467*	.22
Posttreatment	Hippotherapy	25	19.31	0.83–731.36			
	Barrel	19	50.51	0.72–894.34	147.00	.032†	.71‡

*No significant difference between the groups pretreatment ($P>.05$).
†Statistically significant difference between the groups posttreatment ($P<.05$).
‡Large effect size.

Table 4: Phase I Changes in Symmetry of Adductor Muscle Activity: Number of Children According to GMFCS Level

	Horse Group		Barrel Group	
GMFCS	Better	Worse	Better	Worse
Level I	12	2	8	5
Level II	3	1	1	1
Level III	2	0	0	3
Level IV	5	0	0	1

ing a statistically significant improvement in symmetry during ambulation. The barrel-sitting group had a slight mean increase (decline) in the adductor muscle asymmetry score of 1.92mV. This change was not significantly different, indicating no effect on symmetry of muscle activity during walking after barrel-sitting (table 2).

Between-Group Analysis

There was no difference in adductor muscle asymmetry between the groups prior to the interventions of hippotherapy or barrel-sitting. After intervention, the hippotherapy group demonstrated significantly less adductor muscle asymmetry than the barrel-sitting group (table 3).

After the 10-minute hippotherapy intervention, children in all GMFCS levels showed improved adductor muscle symmetry, including the 2 children with level III and the 5 children with level IV (table 4). None of the children in GMFCS levels III and IV responded positively to the barrel. The interaction between groups and GMFCS levels was not significant because there was an insufficient number in each of the subcategories.

METHODS: PHASE II

Long-Term Effects of Hippotherapy

Evidence of immediate improvement in symmetry of adductor muscle activity during walking after a single hippotherapy session may suggest strategies for the physical therapy and orthopedic treatment of children with spastic CP. It is logical, however, to question whether the positive effects on adductor symmetry occur over a series of hippotherapy sessions and are sustained after hippotherapy has been discontinued. Thus, phase II of the study was designed to answer this question with a smaller number of children.

Phase II Participants

As children were recruited and enrolled in phase I of the study, they were invited, in order of enrollment, to also participate in phase II, a 36-week study. The first 6 children to accept all study conditions were accepted for both phases. The selection was done prior to phase I randomization and testing to avoid bias in selecting children who might be deemed responsive to hippotherapy and good candidates for this type of intervention. They received free hippotherapy services for their participation and were required to obtain a complete physician's referral and evaluation prior to participation in the 12 weeks of treatment. Phase II subject demographics are outlined in table 5.

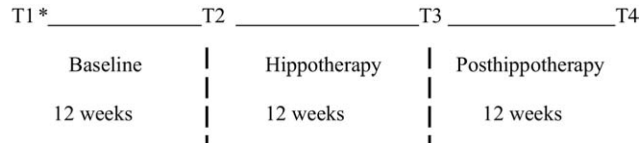

Fig 2. Phase II testing (T) intervals. *T1=phase I pretest.

Phase II Design and Intervention

Phase II was a 36-week repeated-measures design divided into three 12-week segments: baseline (no hippotherapy), treatment, and posttreatment (no hippotherapy). The 6 children each received a once-weekly session of hippotherapy for 12 weeks during the treatment portion of the 36-week protocol. The children were tested on all measures at 4 intervals: T1 (the EMG data for T1 were the phase I pretest and marked the beginning of the 36 weeks of phase II), T2 (12 weeks later just prior to the intervention), T3 (after 12 weeks of intervention), and T4 (12 weeks after the termination of the intervention) (fig 2).

The hippotherapy treatment followed a standard 30-minute (approximately) hippotherapy protocol,[11] which was modified to address each child's treatment goals. During initial warm-up, the child relaxed to the horse's rhythmic movement and adjusted to the feel of a dynamic centered sitting position. At this stage, the horse's walk was in straight lines and gentle curves. Gradually the challenge to the child was increased by modifications to the movement: introduction of figures such as circles or serpentines to challenge lateral weight shift and midline postural control, lengthening the horse's stride to transmit greater movement amplitude through the child's pelvis and trunk, accelerating/decelerating the walk to challenge anticipatory or feedback postural control, and walking on uneven terrain to incorporate predictive visual environmental cues. Specific exercises were also added as appropriate: changing position on the horse to improve dynamic postural control, core stability, and motor planning (eg, backward sit, supine to sit, trunk rotation, and side-sit) and upper-extremity exercises for stretching, reaching, and crossing midline. After the initial few sessions, the children in this study used a saddle and stirrups to facilitate lower-extremity strengthening, graded midrange control, and coordination through exercises such as partial stand in the stirrups (slight hip and knee flexion) with or without arm

Table 5: Phase II Subject Demographics

Subject no.	Age (y)	Sex	Type of CP	GMFCS	Walking Aids/Orthotics
1	5	M	Spastic diplegia	II	Bilateral AFOs
2	7	F	Spastic diplegia	III	Posterior walker; bilateral AFOs
3	8	M	Spastic quadriplegia with mild athetoid movement	III	Posterior walker
4	9	F	Spastic diplegia	II	No aids or orthotics
5	9	M	Spastic diplegia	III	Posterior walker; bilateral AFOs
6	12	M	Spastic quadriplegia	IV	Posterior walker with seat; bilateral AFOs

Abbreviations: AFO, ankle-foot orthosis; F, female; M, male.

support and sit-stand-sit. The level IV child required moderate to maximum assistance with the stirrup exercises and was unable to perform position changes. The session concluded with a short cool-down phase as needed.

All parents agreed to continue the child's usual therapies and activities throughout the 36 weeks of phase II, and no surgeries or BTX-A treatments were planned or occurred during the study.

Outcome Measures and Testing Protocols

A current disablement model, the World Health Organization's ICF,[25] suggests an interrelationship among body function (such as spasticity and adductor asymmetry), activities/tasks, and life participation. Based on this model, we hypothesized that if improved adductor symmetry were sustained, a child's ability to perform functional motor activities might improve as well as feelings about self-competence. Phase II included the following outcome measures for the following domains.

Adductor muscle activity using surface electromyography. All methodology for sEMG placement and recording was as described in phase I of the study, with the exception of the sEMG normalization procedure and the lack of an immediate posttest. In phase I of the study, the preintervention walking trial sEMG data were used as the reference activity for comparison to the postintervention trials because the electrodes were not removed during the single testing session. For phase II, sEMG data for each walking trial were normalized to the peak voluntary contraction with a 500-ms window using MyoResearch software. This normalization method is appropriate for repeated measures of dynamic movement.[21]

Gross Motor Function Measure-66. This measure is a 66-item version of the GMFM-88 that was developed and validated as an evaluative assessment of gross motor function in children with cerebral palsy. It has shown the same good reliability and validity as the GMFM-88, but with fewer test items and improved interval scoring.[26] We elected to test all children with their customary orthoses in order to test their highest functional ability. The physical therapist performing the assessments had 30 years of experience in pediatrics and extensive clinical use of the GMFM and was additionally trained using the GMFM training CD-ROM.

Table 6: Phase II Adductor Muscle Asymmetry Scores* at Each Testing Interval

Subject	12 Weeks Pre-HPOT T1	Immediately Pre-HPOT T2	Immediately Post-HPOT T3	12 Weeks Post-HPOT T4
1	11.6	13.2	3.95	2.35
2	10.5	8.7	6.1	6.75
3	14.3†	8.3	7.2	5.3
4	9	7.5	3.93	5.65
5	3.55	4.65	7.3‡	3.8
6	7.4	8.7	3.2	2.55

NOTE: Scores represent percent peak voluntary contraction.
Abbreviation: HPOT, hippotherapy.
*Decreasing score indicates improved symmetry.
†At T1, subject 3 was very anxious and showed increased spastic-athetoid movement during testing. This might explain the unusually high baseline (T1) asymmetry score compared with T2.
‡After 4 weeks of hippotherapy, subject 5 announced that he would no longer be using his walker and refused to use it for further testing. At T3, he walked 1 trial completely unaided, although with obvious increased left-right trunk flexion during lateral weight shift. This asymmetric gait was reflected in his increased adductor asymmetry scores, which eventually dropped to baseline levels, T4, while he continued ambulating without the walker.

Table 7: Phase II: GMFM66 Scores at Each Testing Interval

Subject	12 weeks Pre-HPOT T1	Immediately Pre-HPOT T2	Immediately Post-HPOT T3	12 weeks Post-HPOT T4
1	56.62	56.86	63.33	65.33
2	51.85	50.62	54.38	53.62
3	47.68	47.09	50.62	52.62
4	65.63	65.33	70.39	68.86
5	58.56	59.86	63.63	64.98
6	44.31	46.32	49.21	50.09

Abbreviation: HPOT, hippotherapy.

The Self-Perception Profile for Children, ages 8 to 13, and the Pictorial Self-Perception Profile for Young Children, ages 4 to 7. These assessments are in self-report format for children with or without disabilities, with content validity established on more than 2000 children.[27] Reliability across all subscales ranged from .73 to .86. The scales are designed to assess children's self-judgments across different domains by having the child indicate, through pictures or written description, which imaginary child is more like the tested child. The instrument for the younger children has been modified to be more developmentally appropriate for that age group.[28] Scoring for both self-perception profiles is on a scale of 1 to 4, with 1 indicating low perceived competence and 4 indicating high perceived confidence. For each domain, the 6 items are scored and totaled, and a mean score for each domain is then calculated. The domains are listed in tables 8 and 9.

Data Analysis

Because of the small number of subjects in phase II and the variability of ages and characteristics, test results are reported in table or chart format for visual analysis.

Table 8: Pictorial Self-Perception Profile for Young Children

	12 Weeks Pre-HPOT T1	Immediately Pre-HPOT T2	Immediately Post-HPOT T3	12 Weeks Post-HPOT T4
Subject 1				
Peer acceptance	3.33	3.5	3.5	3
Physical competence	3.33	3	2.6	3.3
Maternal acceptance	1.67	2	2.5	1.8
Global self-worth*	3.5	3.8	4	3.6
Subject 2				
Peer acceptance	3.67	3.8	3.6	4
Physical competence	3.5	3.5	4	4
Maternal acceptance	3.67	3.5	4	3.6
Global self-worth*	3.17	3	4	4

NOTE: Age 4y to 7y mean scores at each testing interval for each domain.
Abbreviation: HPOT, hippotherapy.
*Feelings about self that are independent of a specific area of competence.

Table 9: Self-Perception Profile for Children

	12 Weeks Pre-HPOT T1	Immediately Pre-HPOT T2	Immediately Post-HPOT T3	12 Weeks Post-HPOT T4
Subject 3	Unable to comply with test directions			
Subject 4				
Cognitive competence	2.66	2.16	2.2	2.67
Social acceptance	3	3.66	3.8	3.8
Athletic competence	2.33	1.8	1.5	1.3
Physical appearance	3.66	3.66	3.5	3.67
Behavioral acceptance	3.5	3.16	3.8	4
Global self-worth*	2.83	3.66	3	3.8
Subject 5				
Cognitive competence	3.5	2.8	3.5	3.16
Social acceptance	3.16	4	4	3.83
Athletic competence	1.66	1.33	2.3	2.83
Physical appearance	3	3.16	3.3	3.30
Behavioral acceptance	2.33	4	4	4.00
Global self-worth*	3	3.8	3.8	4.00
Subject 6				
Cognitive competence	3.5	3.66	3.5	4
Social acceptance	3.16	3.33	2.8	2.33
Athletic competence	1.66	2.16	3.5	3.33
Physical appearance	3	3.16	3.6	3
Behavioral acceptance	2.33	2.66	3.8	3
Global self-worth*	3	2.66	3.6	3.33

NOTE: Age 8y to 13y mean scores at each testing interval for each domain.
Abbreviation: HPOT, hippotherapy.
*Feelings about self that are independent of a specific area of competence.

RESULTS: PHASE II

Adductor Asymmetry

After 12 weeks of weekly hippotherapy, 4 of 6 children (subjects 1, 2, 4, 6) showed improved adductor muscle symmetry during walking. The improvement was maintained 12 weeks posthippotherapy. Subject 3 did not show baseline stability, so improvement posttreatment is open to question. Subject 5 did not show improved adductor symmetry after hippotherapy, but this may be a result of extraneous factors (see table 6, footnotes).

Gross Motor Function Measure

All 6 children improved on the Gross Motor Function Measure-66 and maintained improved function over baseline 12 weeks posttreatment (table 7). One child began walking without a walker for the first time after 4 weeks of hippotherapy. Figure 3 shows the changes in the GMFM scores after the hippotherapy phase compared with the baseline and posttreatment phases.

Self-Perception Profiles

The results for these tests were varied. Five of the 6 children completed all Self-Perception Profiles (subjects 1, 2, 4, 5, 6), and all improved in at least 1 area (tables 8 and 9). Subject 3 did not complete this testing. During initial testing attempts, he frequently looked away from the pictures as if unwilling or unable to understand the questions.

DISCUSSION

This study demonstrates that hippotherapy may be an effective treatment tool for reducing adductor muscle asymmetry in children with spastic cerebral palsy. The effect size of the phase I hippotherapy intervention (1.32) is considered very large and has been described as a difference that is grossly observable.[29] On several occasions, this positive effect was observed by family members with comments about how much better the child appeared to be walking for the posthippotherapy walking trials: "He looks more balanced," or, "She seems to be walking more easily."

The rhythmic, left-right symmetrical walking movement of the horse could be the critical factor, repeatedly shifting the child back and forth across midline, while the girth of the horse provides gentle, sustained stretch to spastic adductor muscles. The powerful thrusts of the horse's legs provide strong vestibular and proprioceptive stimulation and heighten body awareness, while repeated small postural adjustments help the child gain a more normative sense of midline and symmetrical weight-bearing.

However, improved adductor symmetry alone does not explain the children's improved ability to perform motor tasks, particularly because 2 of the subjects did not improve adductor

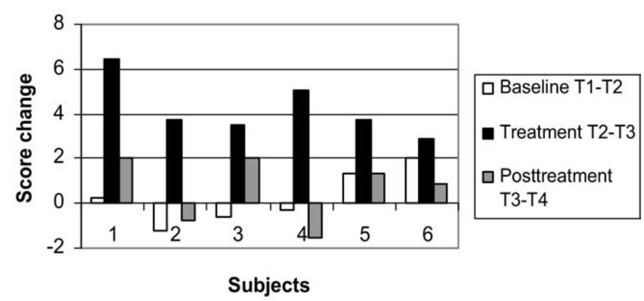

Fig 3. GMFM-66 score changes after baseline, treatment, and posttreatment phases.

muscle symmetry over 12 sessions, yet did improve in gross motor function. Further research might focus on additional impairments that are thought to be positively affected by hippotherapy, such as muscle tone, trunk coordination, core stabilization, mobility, and sensory organization, as factors contributing to improved motor function. Changes in feelings of self-competence also merit further study, particularly as they relate to a child's willingness to explore and learn new motor activities.

Undoubtedly, many impairments related to multiple systems are affected by the horse's movement and rhythm, and the therapist's chosen strategies in directing the equine movement are essential to the success of hippotherapy. For example, as a child adapts to the movement and begins to sit symmetrically on the horse, the therapist carefully modifies the horse's movement and/or child's position to promote greater postural challenges and to facilitate the development of new or more finely tuned motor strategies relevant to the child's specific treatment goals. An average-size horse takes 90 to 110 steps a minute, requiring the child to shift weight and make subtle postural adjustments with every step. The 2700 to 3300 stepping repetitions over a typical 30-minute session, combined with high patient motivation, provide the ideal practice environment for learning new motor strategies,[30] which are then available to the child for functional tasks in daily life. Motor strategies that may improve include control of mediolateral and anteroposterior postural sway, postural adaptation to a changing environment, anticipatory and feedback postural control, and more effective use of multisensory inputs related to posture and movement. Such strategies also are considered essential for the development of normative postural control and movement and are thought to be building blocks for independent walking and related motor tasks.[31]

The ICF model suggests the importance of addressing all areas of child well-being as components of a patient's treatment protocol. In addition to the improvements shown in this study in the domains of body function and task/activity, child and sex-specific changes in feelings of self-competence provide interesting insights related to participation and quality of life. For example, the boys, who made gains in motor skills, also showed positive changes on the SPPC or Pictorial Self-Perception for Young Children in their feelings about athletic or physical competence. It is unclear whether this is related to improved motor ability or to the unique sense of achievement sitting on a powerful, moving horse. However, parents of 2 of the boys reported more enthusiastic participation at school and on the playground after hippotherapy. In the girls, the SPPC or Pictorial Self-Perception for Young Children indicated positive changes in behavior and/or parental acceptance, possibly reflective of the parents' pride in their child's new accomplishments both on and off the horse. While hippotherapy seems to provide great pleasure to all of the children who participate, the variety of changes in feelings of self-competence may reflect the unique personalities and values of each child and their family.

No adverse events were experienced during either phase. The children in phase II had perfect attendance, including all testing sessions.

Study Limitations

One limitation of this study was our inability to measure adductor activity during other functional motor tasks such as standing, running, and stair-climbing. Blocked randomization by GMFCS level as well as a larger sample size would have yielded more equivalent groups for evaluating the potential relationship between treatment response and level of disability. Another study limitation is the diversity of subjects in the distribution of their spasticity and the inclusion of children with mixed characteristics. A future study that excludes children with mixed types of CP would provide a less diverse population. In phase II, a larger sample of subjects with greater similarity in ages and characteristics—for example, diplegic spasticity with known adductor asymmetry and the same GMFCS level—might yield less varied results with the Self-Perception Profiles.

CONCLUSIONS

Phase I of this study provides evidence that 10 minutes of hippotherapy significantly improves symmetry of adductor muscle activity during walking in 25 children with spastic cerebral palsy. Nineteen children with spastic cerebral palsy who sat quietly astride a barrel for 10 minutes did not show significant change. These results of improved adductor symmetry after hippotherapy and the strong effect size support the findings of the previous pilot study by Benda et al.[18] In the children who received 12 weeks of hippotherapy treatment, the improvement in adductor symmetry may be linked to the gains in functional motor abilities that were sustained 12 weeks posttreatment, particularly in those skills involving upright support such as standing and walking. The improved GMFM scores support the findings of McGibbon et al[11] (twice-weekly hippotherapy for 8 weeks) and Casady and Nichols-Larsen[12] (weekly hippotherapy for 10 weeks). The parents were extremely positive about the beneficial effects of hippotherapy on their children's motor skills. In addition, several commented that hippotherapy gave their children an enhanced confidence in their abilities that carried over into many aspects of the children's daily lives.

This study provides another important piece to the puzzle of understanding the multifaceted nature of hippotherapy and its effects on children with spastic CP. As we enhance our knowledge about the influences of hippotherapy on specific impairments and in various functional domains, we can more effectively treat children with complex problems.

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